

Integrating DERs on the Grid: *Inverter Transient Overvoltage*

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October 23rd, 2015

Agenda

Load Rejection Overvoltage Testing

Ground Fault Overvoltage Testing

Ongoing Pilots and Projects

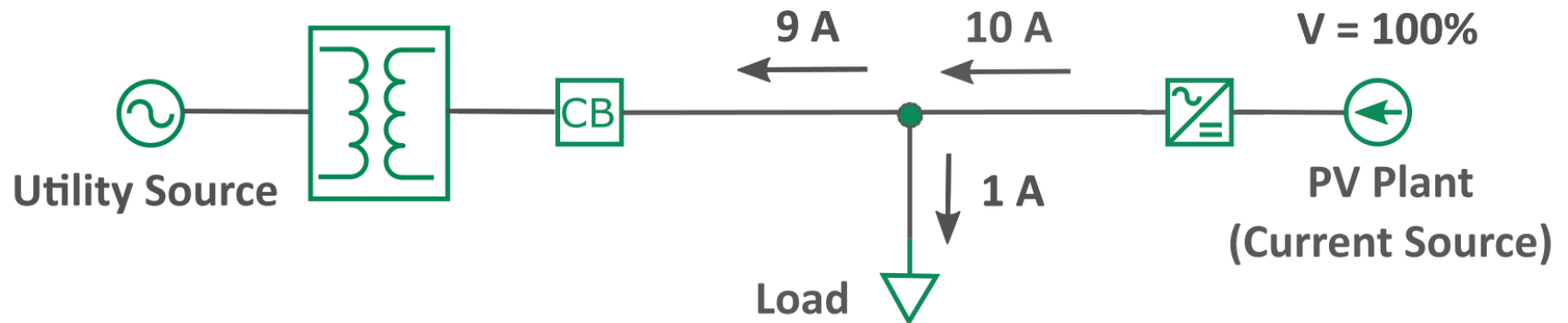


Load Rejection Overvoltage

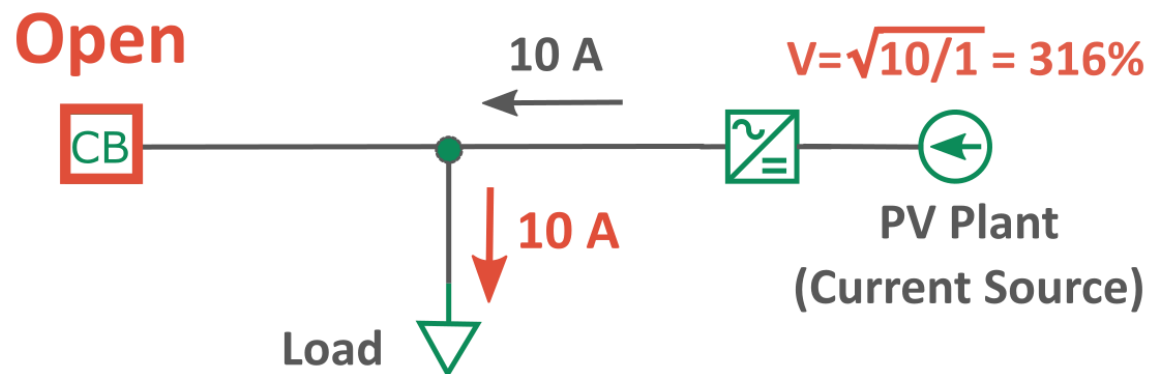
- LRO occurs when a portion of a feeder containing significant PV resources and equal or smaller amount of load becomes disconnected.
- Generation to load ratio (GLR) exceeds unity.
- Theoretical maximum LRO predicted by an ideal current source \sqrt{GLR} .

Load Rejection Overvoltage

Before



After

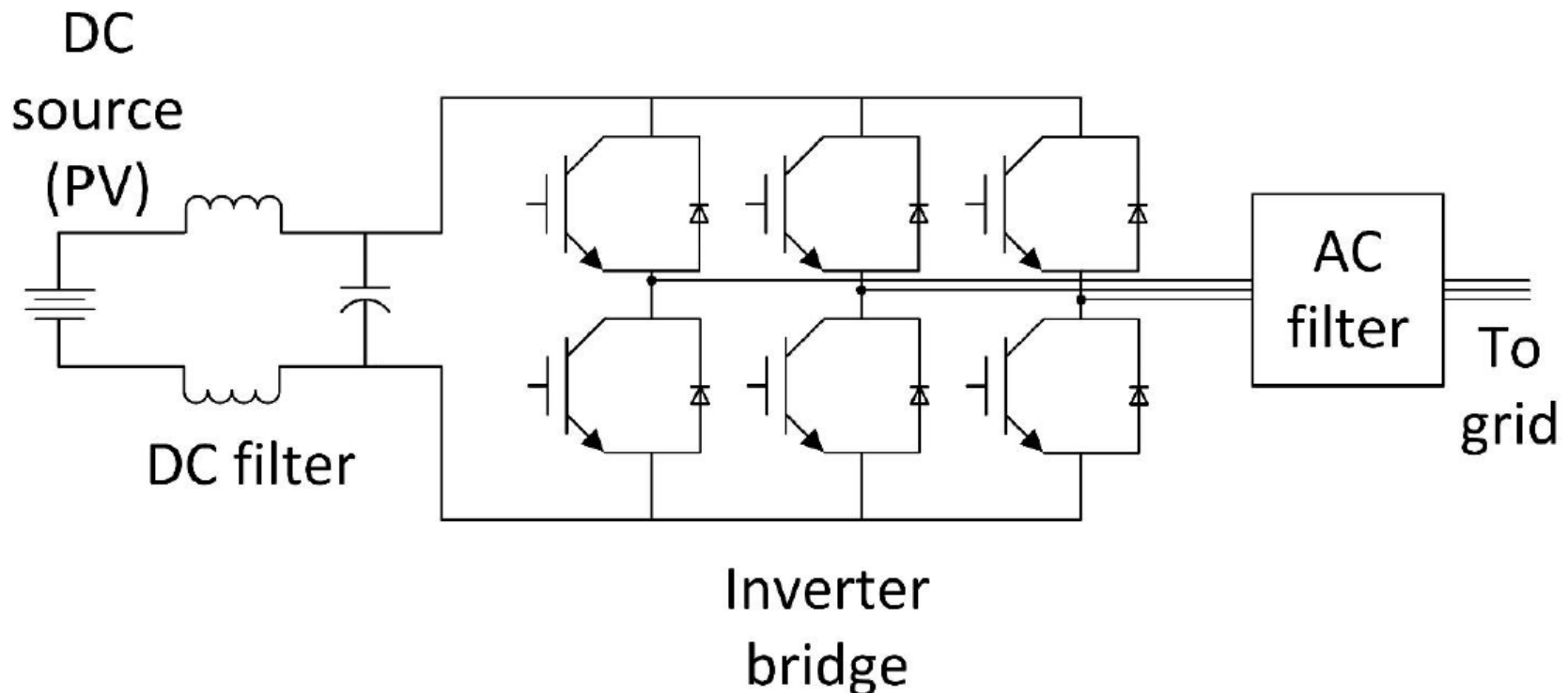


Load Rejection Overvoltage

- Theory and simulation poorly predict LRO because
 - Inverters are more complex than constant current sources
 - Inverters are not a voltage behind impedance
 - Many inverters have a self-protection overvoltage trip

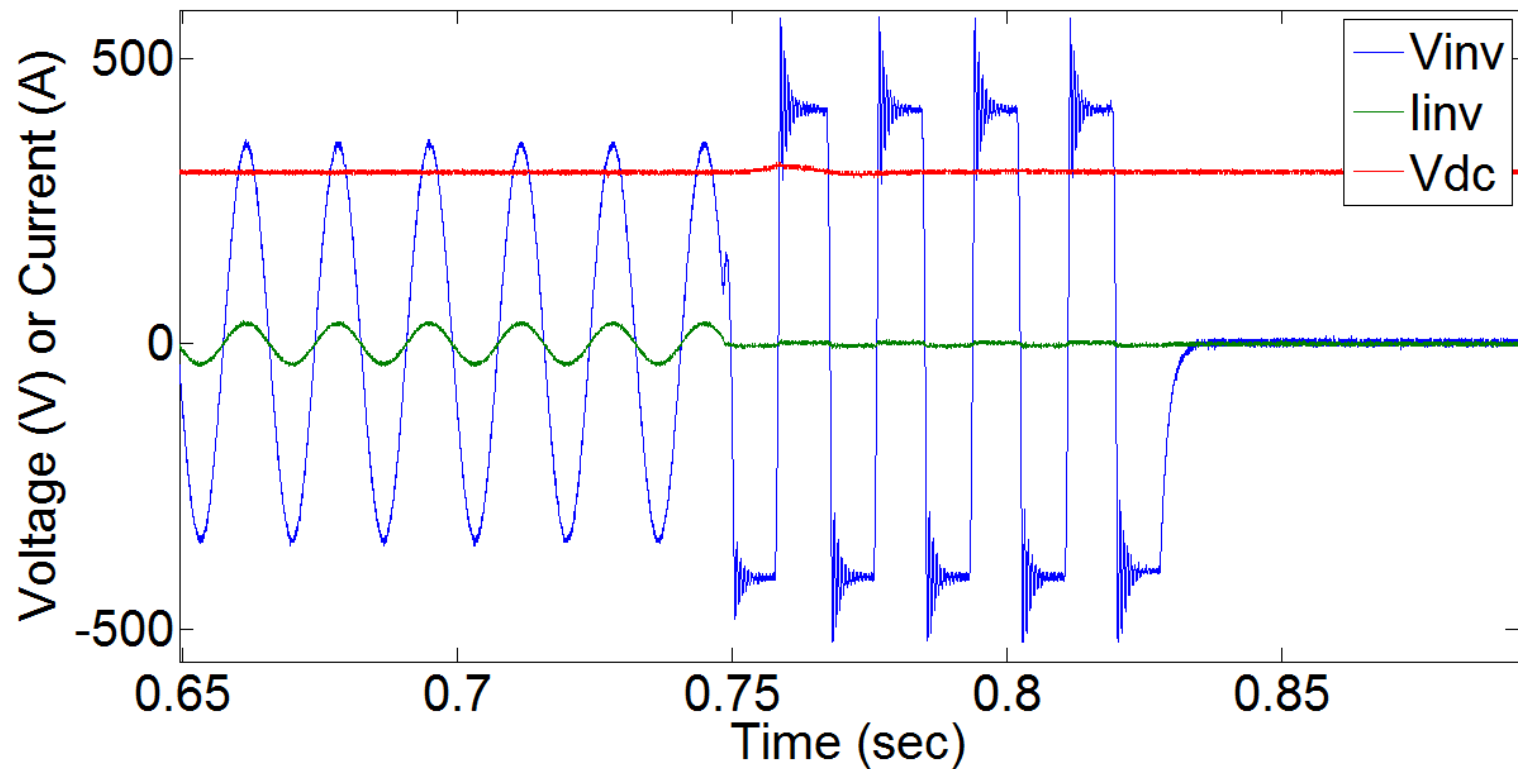
Load Rejection Overvoltage

- Standard inverter topology includes an antiparallel rectifier that enables out-of-phase current flow.
- If the AC side voltage rises above the DC side voltage, the rectifier will clamp the AC peak to the DC voltage.



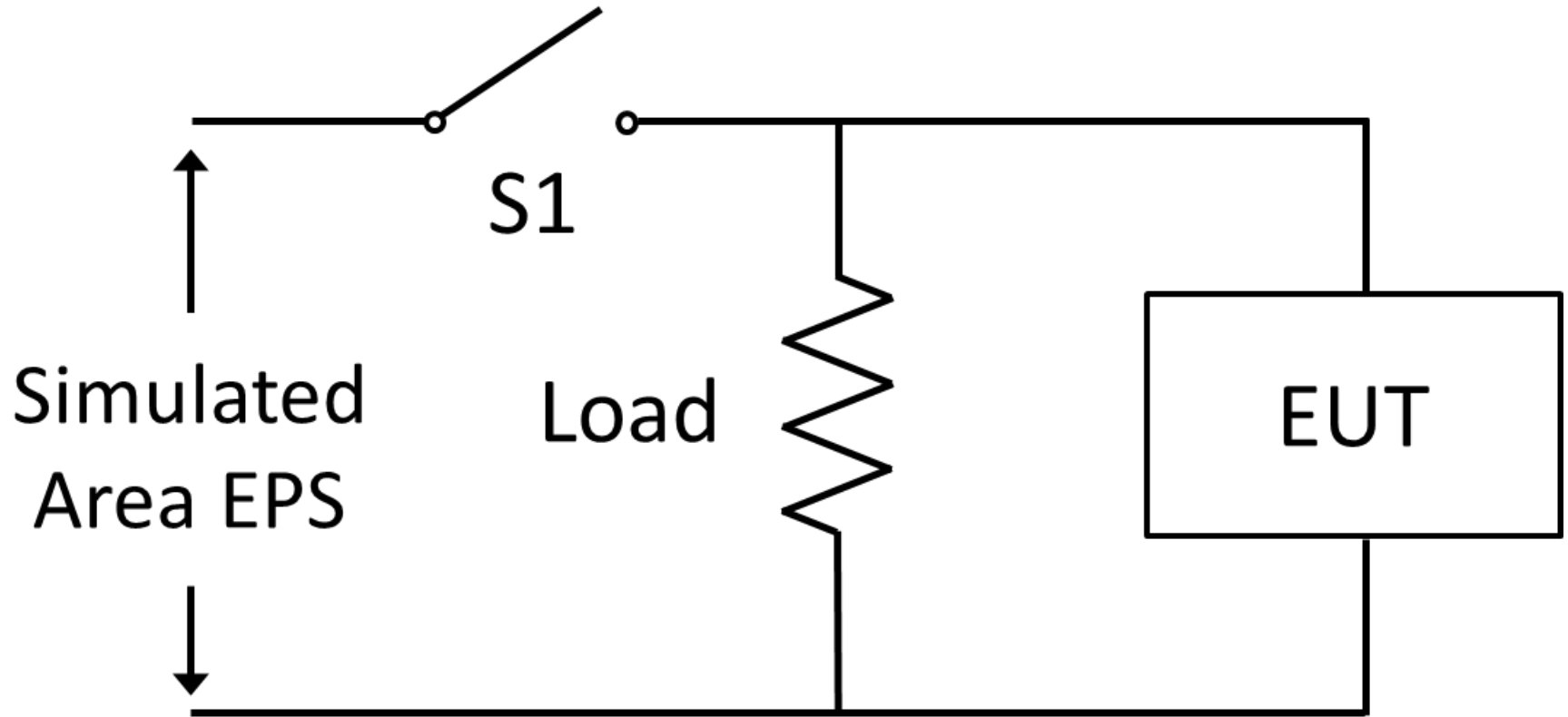
Load Rejection Overvoltage

- At unity or low GLR, output was sinusoidal with varying magnitude near nominal.
- At medium to high GLR, waveform clipped at DC bus voltage.

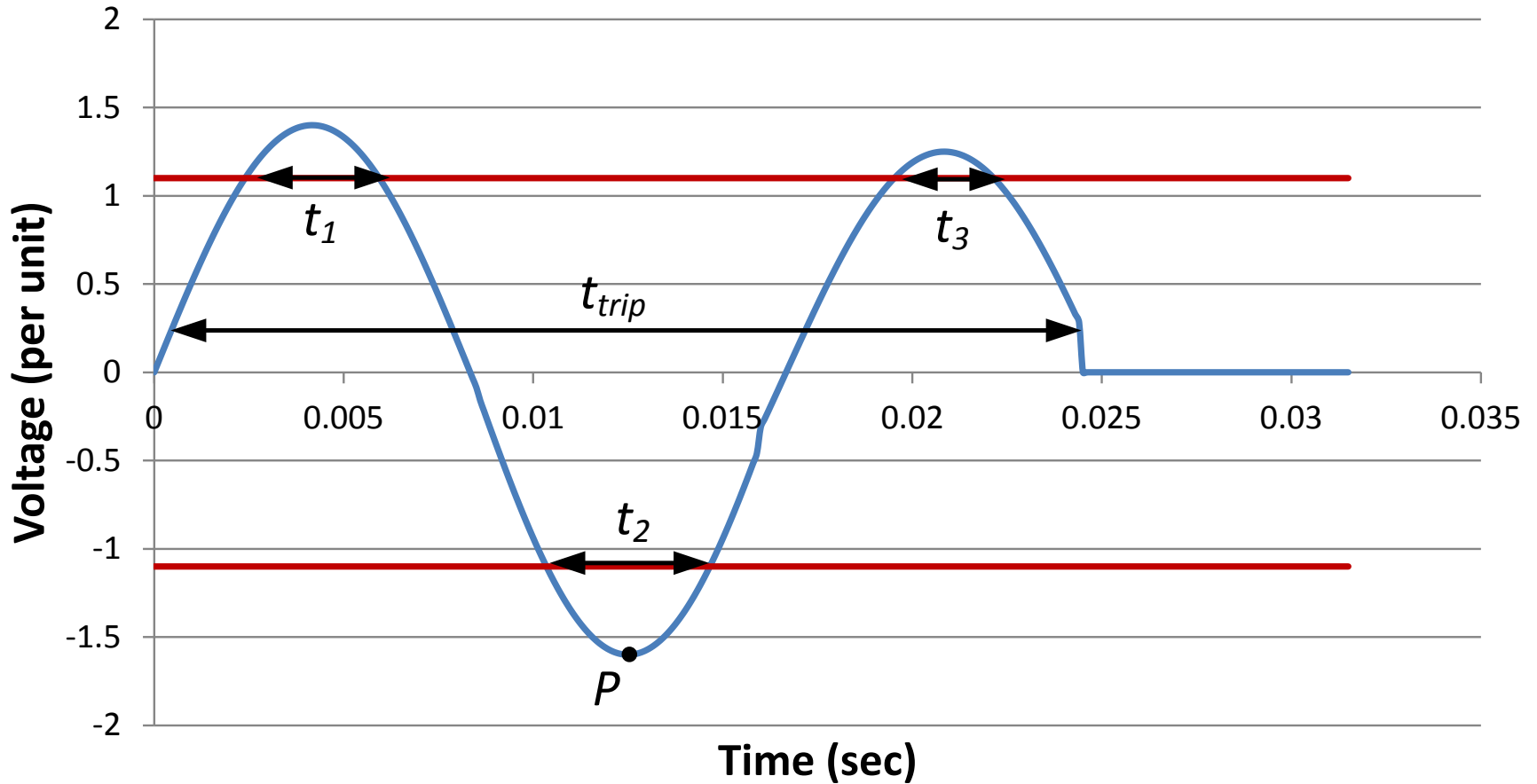


GLR = 10:1

Load Rejection Overvoltage

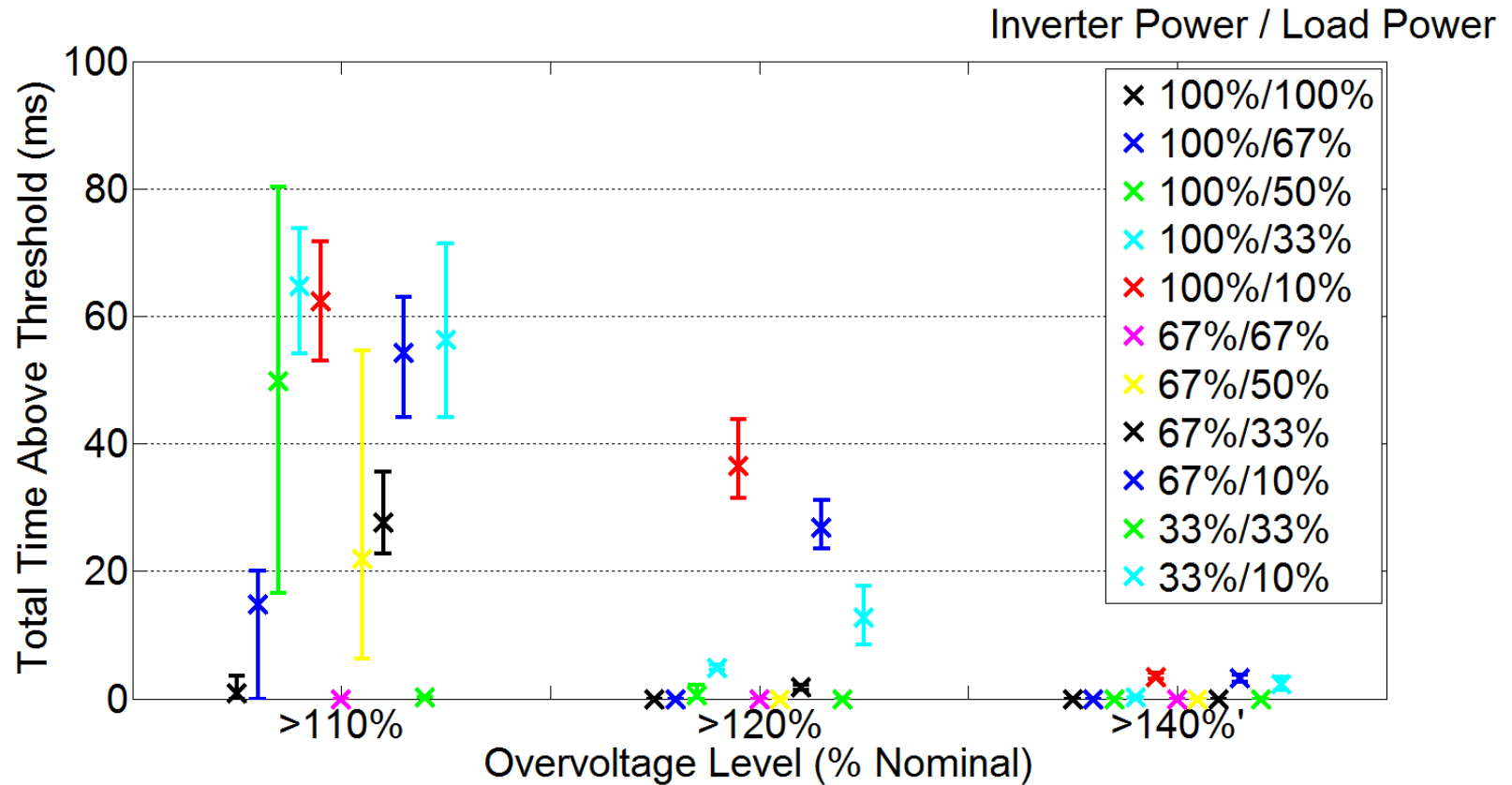


Load Rejection Overvoltage

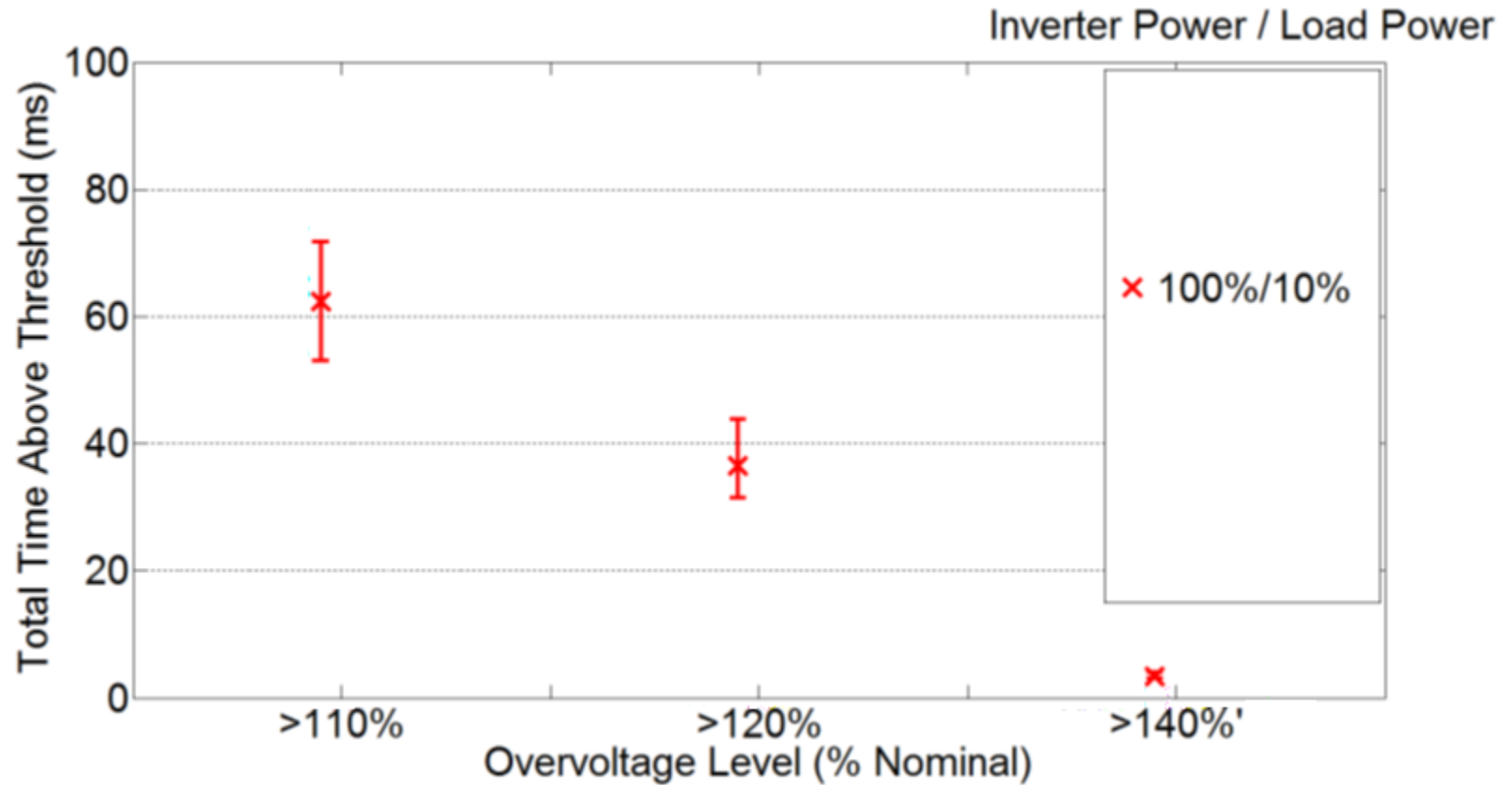


GLR = 10:1

Load Rejection Overvoltage



Load Rejection Overvoltage

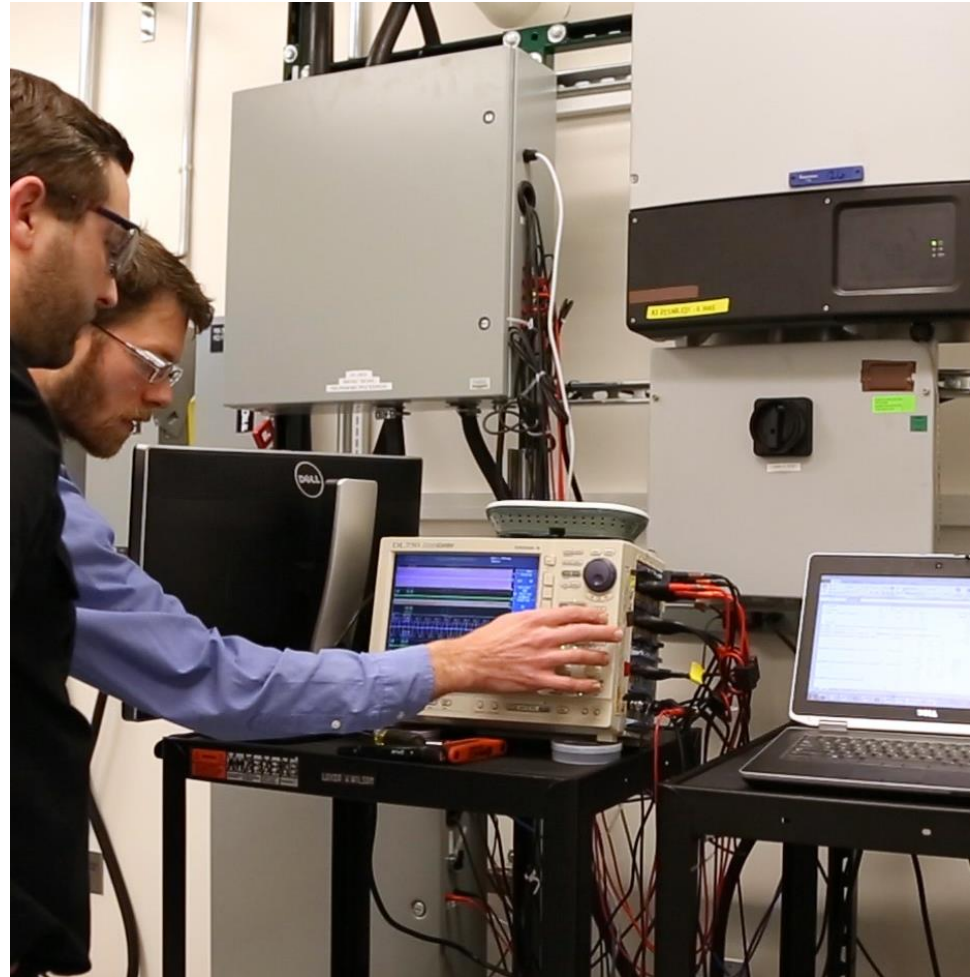


Load Rejection Overvoltage

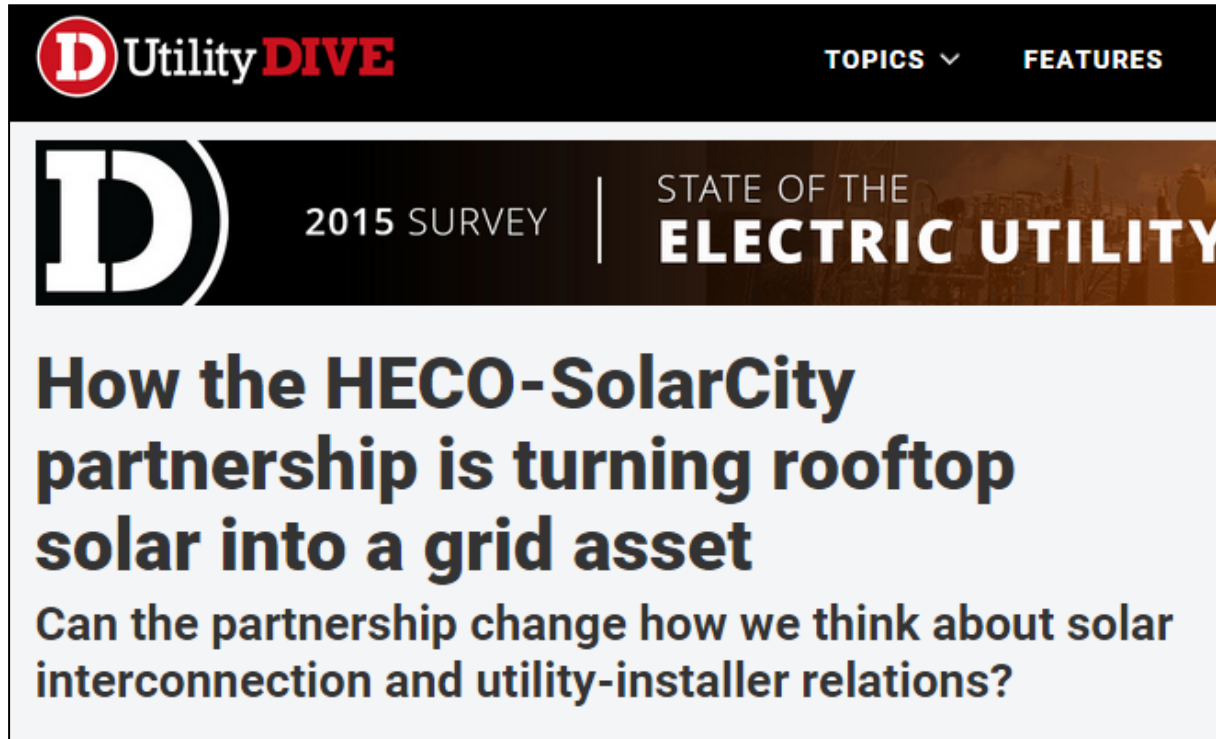
- Inverters responded with much lower over-voltage magnitudes than predicted by simple models of inverters as ideal current sources



- Used to update HECO interconnection requirements. Justified move from 120% to 250% minimum daytime load (MDL) PV penetration.



SolarCity, HECO and NREL testing removed *Transient Overvoltage* as a DER integration challenge



The screenshot shows the Utility Dive website header with the logo and navigation links 'TOPICS' and 'FEATURES'. Below the header is a banner for the '2015 SURVEY | STATE OF THE ELECTRIC UTILITY'. The main article title is 'How the HECO-SolarCity partnership is turning rooftop solar into a grid asset'. The sub-headline reads: 'Can the partnership change how we think about solar interconnection and utility-installer relations?'.



**Hawaiian
Electric**



SolarCity

Agenda

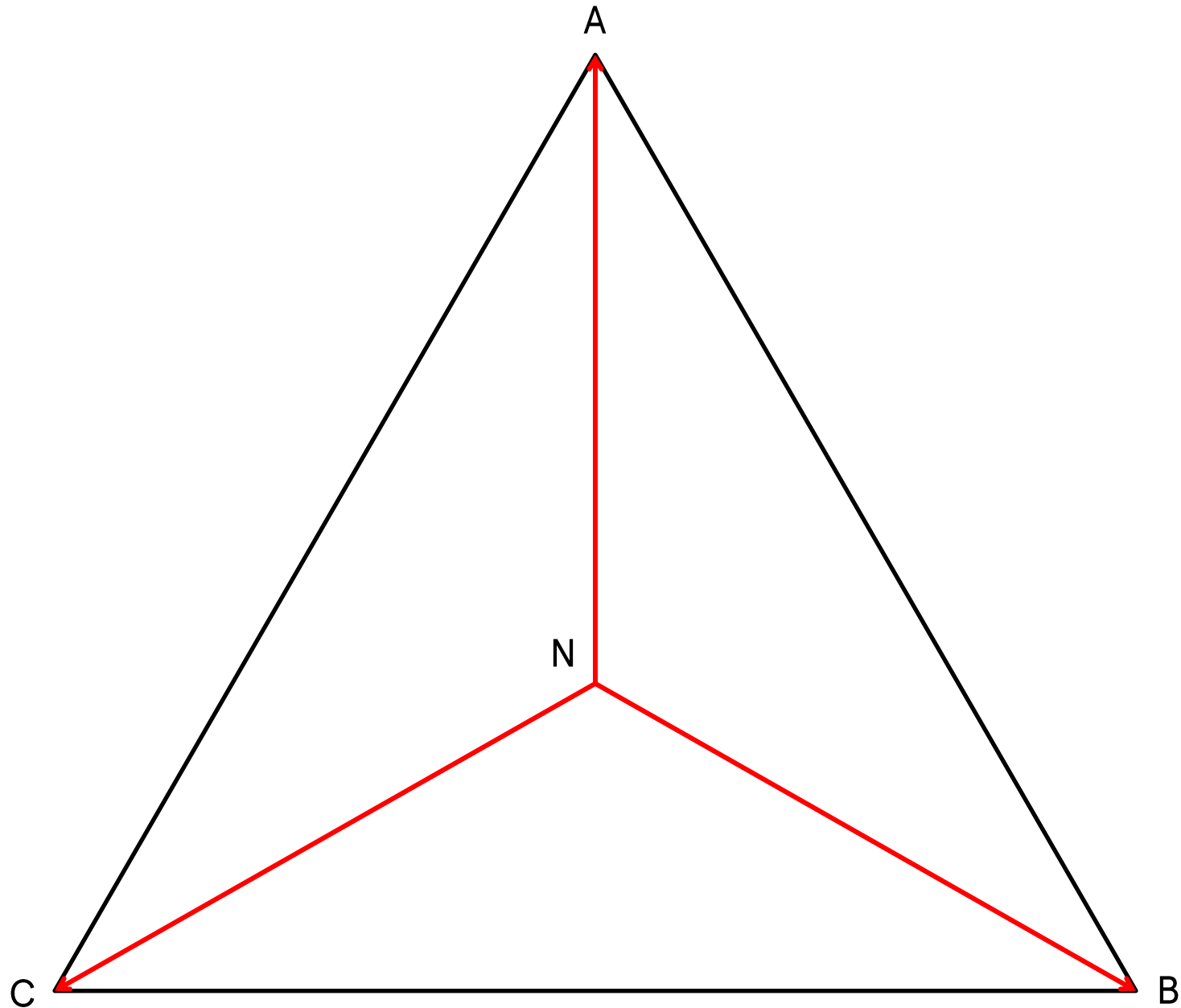
Load Rejection Overvoltage Testing

Ground Fault Overvoltage Testing

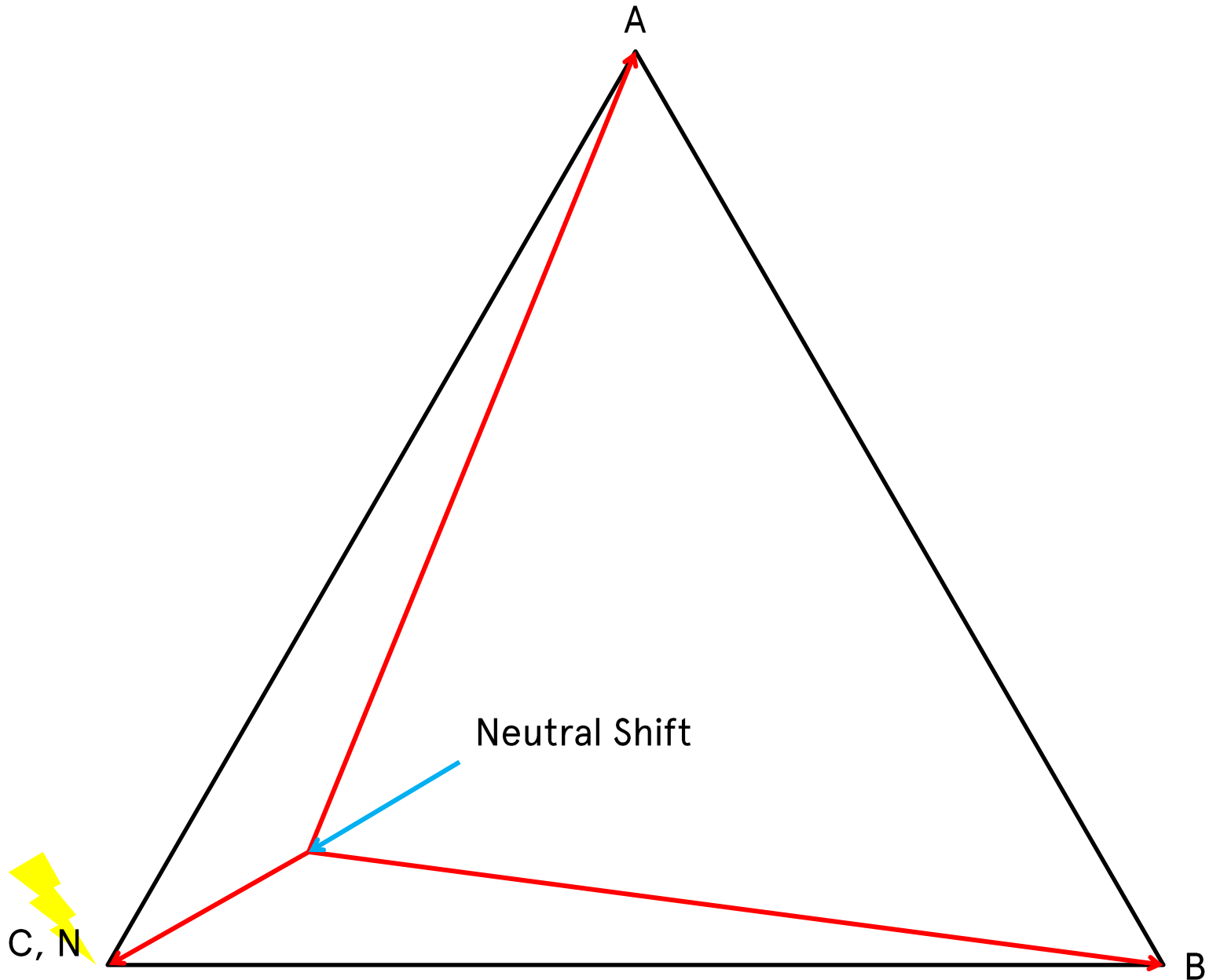
Ongoing Pilots and Projects



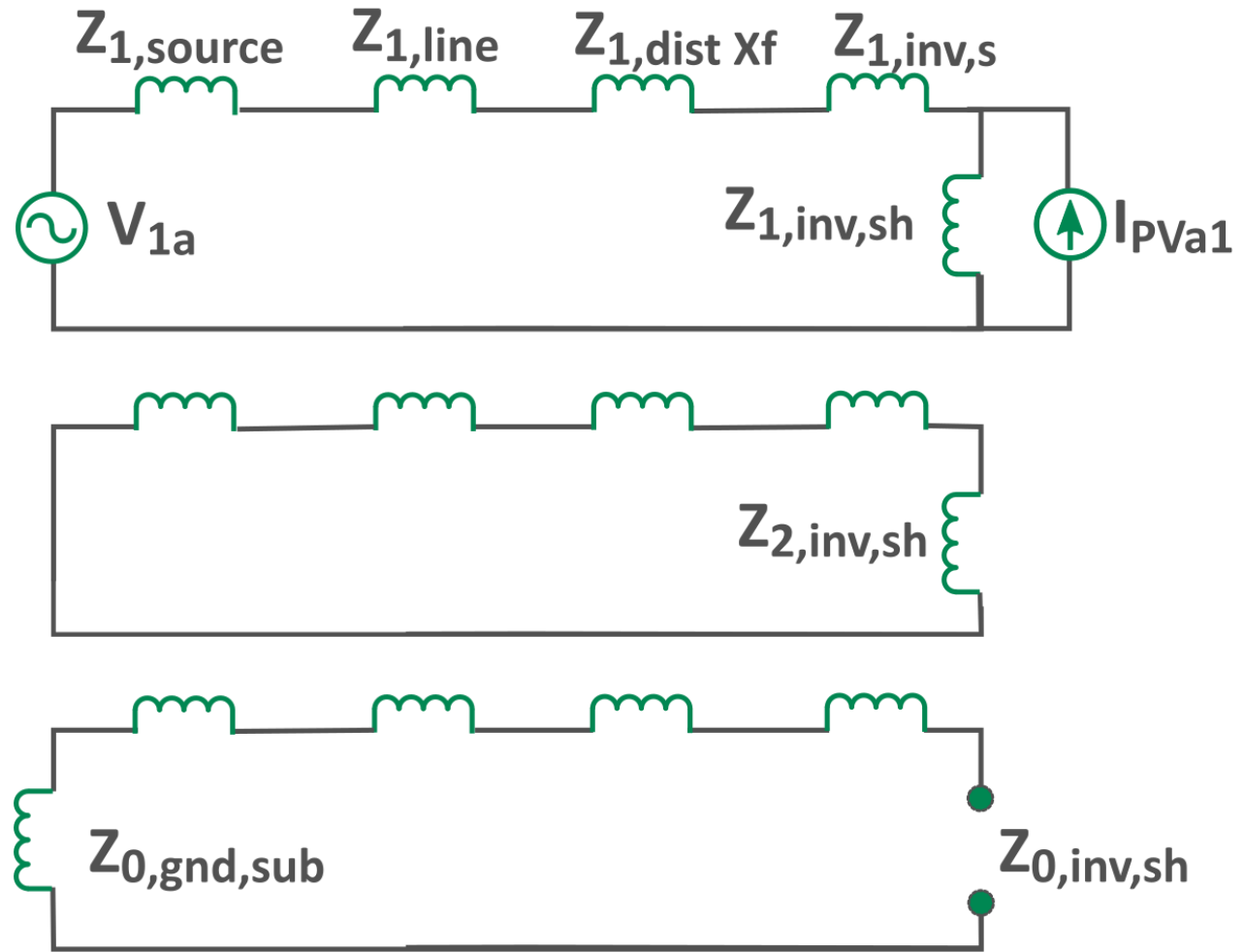
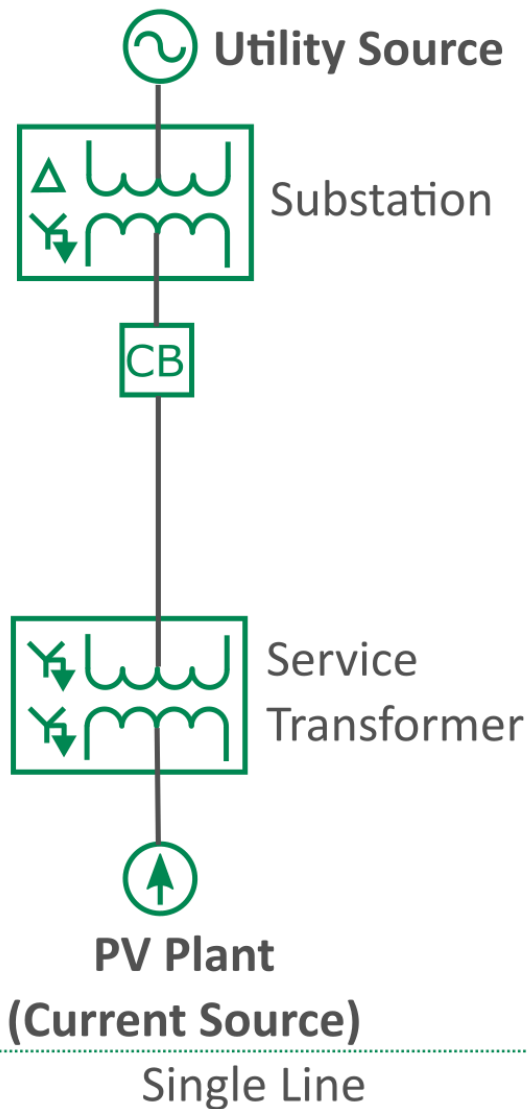
Ground Fault Overvoltage



Ground Fault Overvoltage

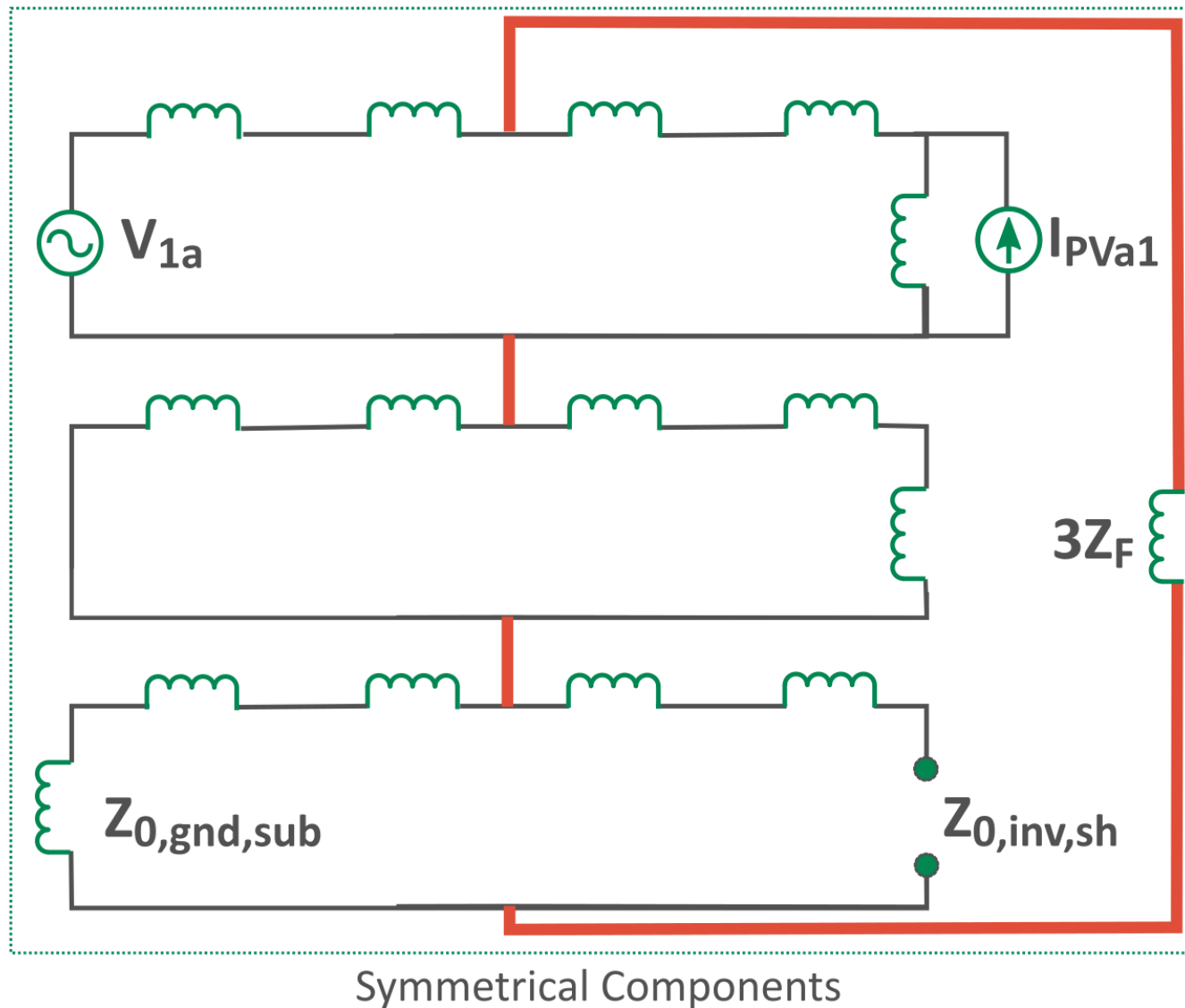
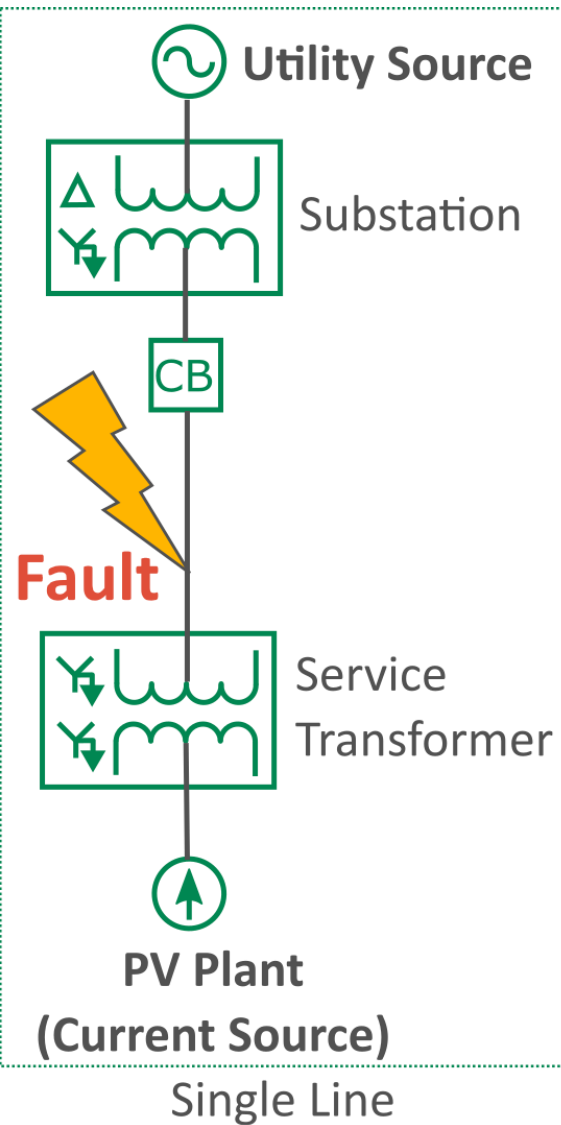


Ground Fault Overvoltage – 0. Normal Condition

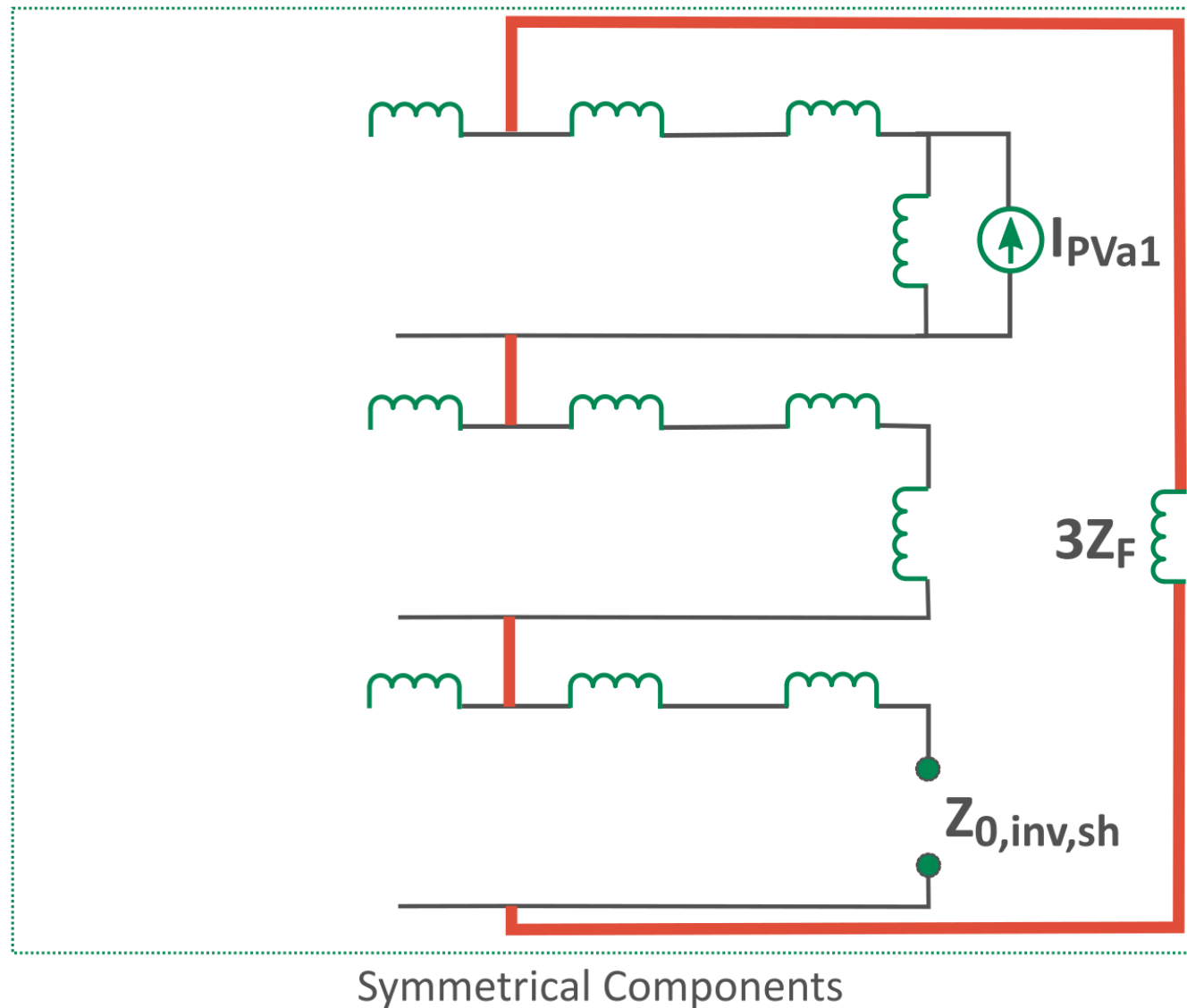
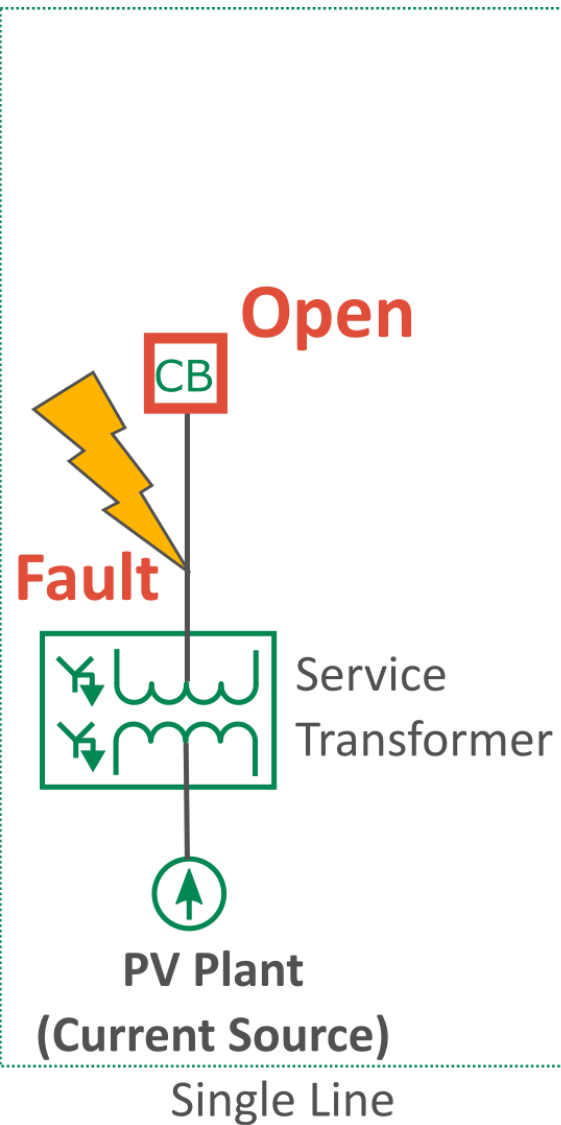


Symmetrical Components

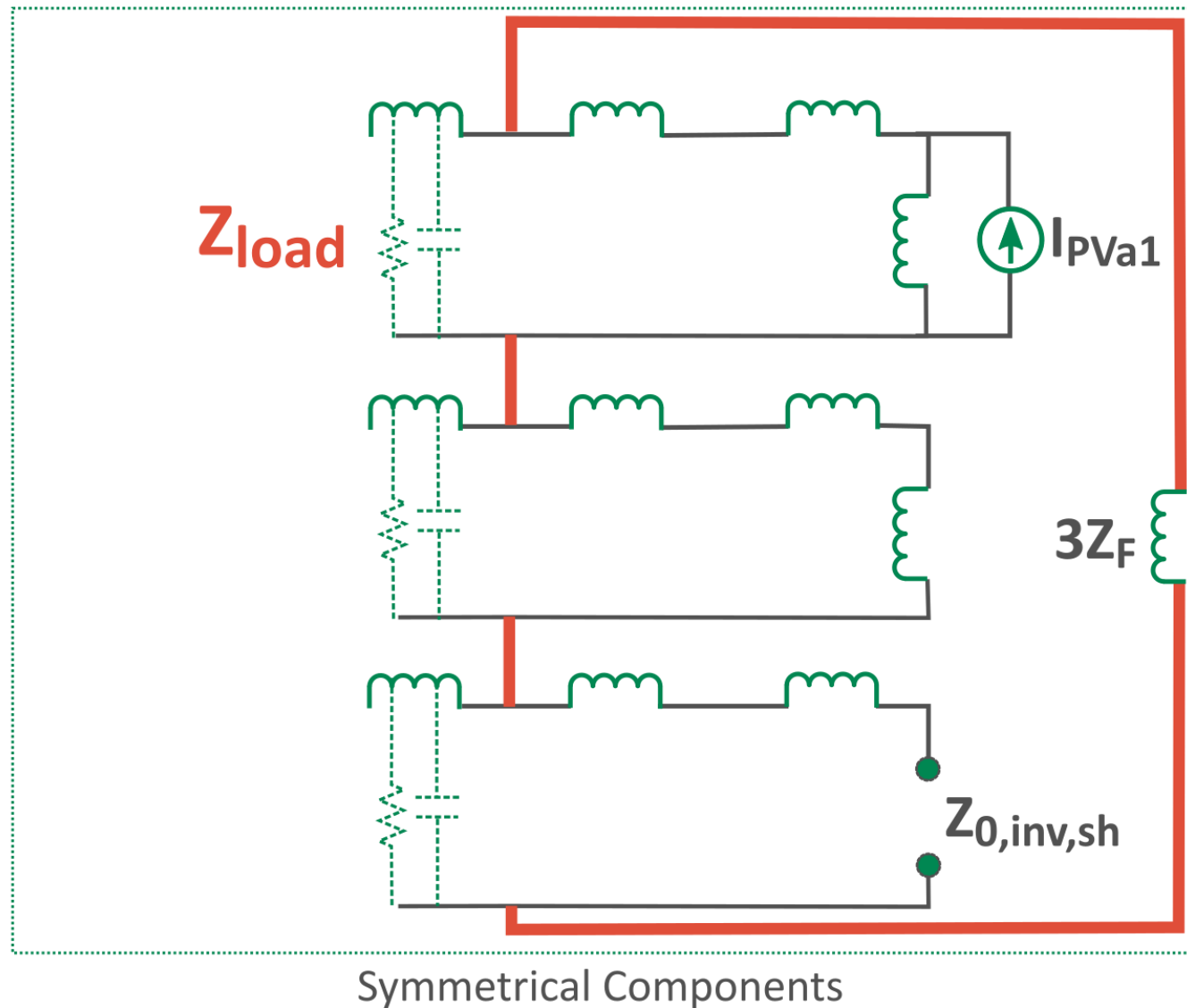
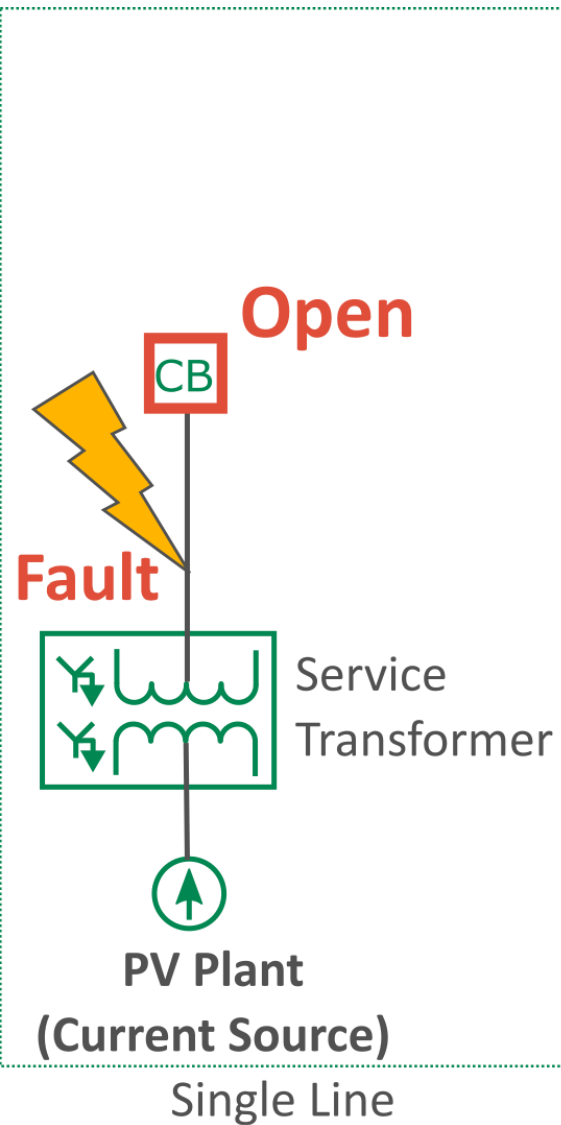
Ground Fault Overvoltage – 1. Fault Happens



Ground Fault Overvoltage – 2. Breaker Opens



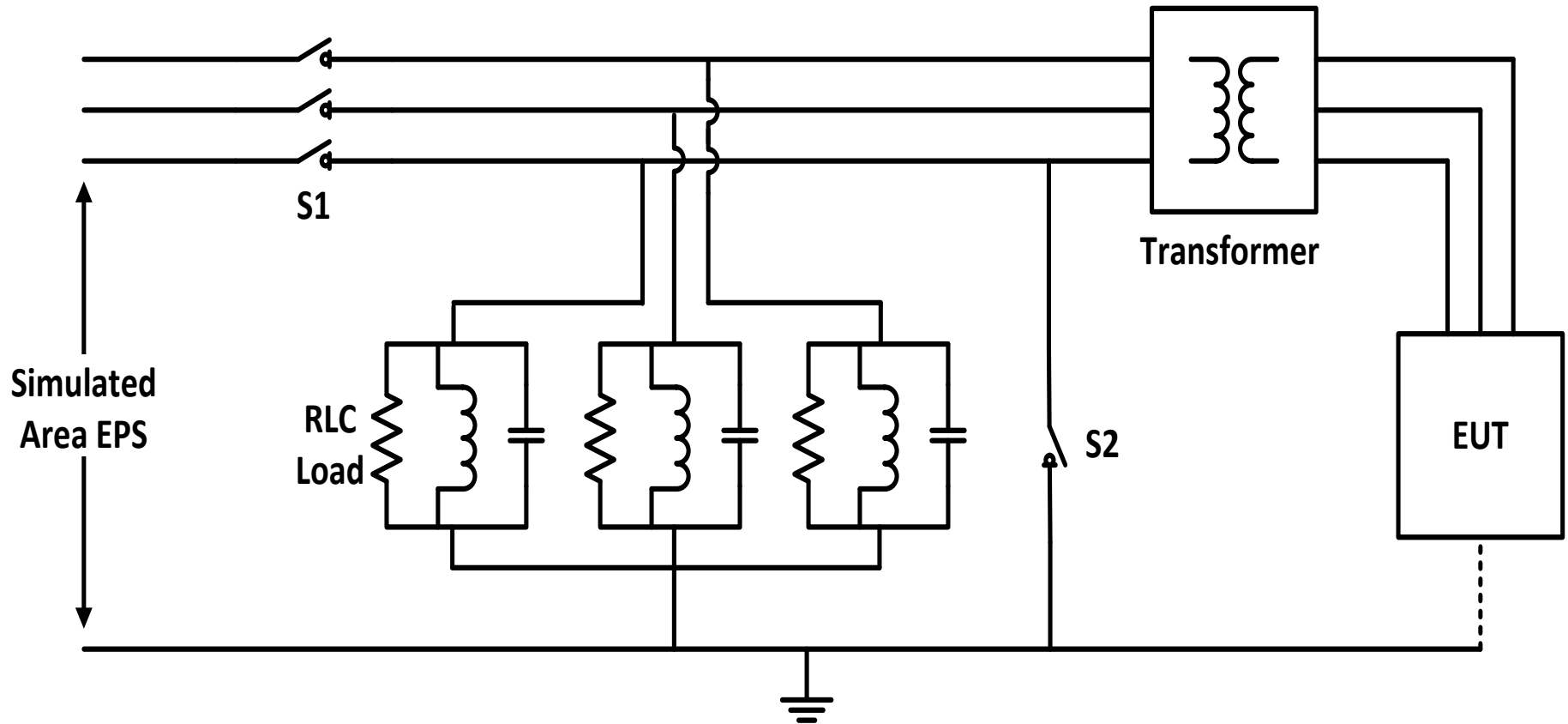
Ground Fault Overvoltage – Must Consider Loads



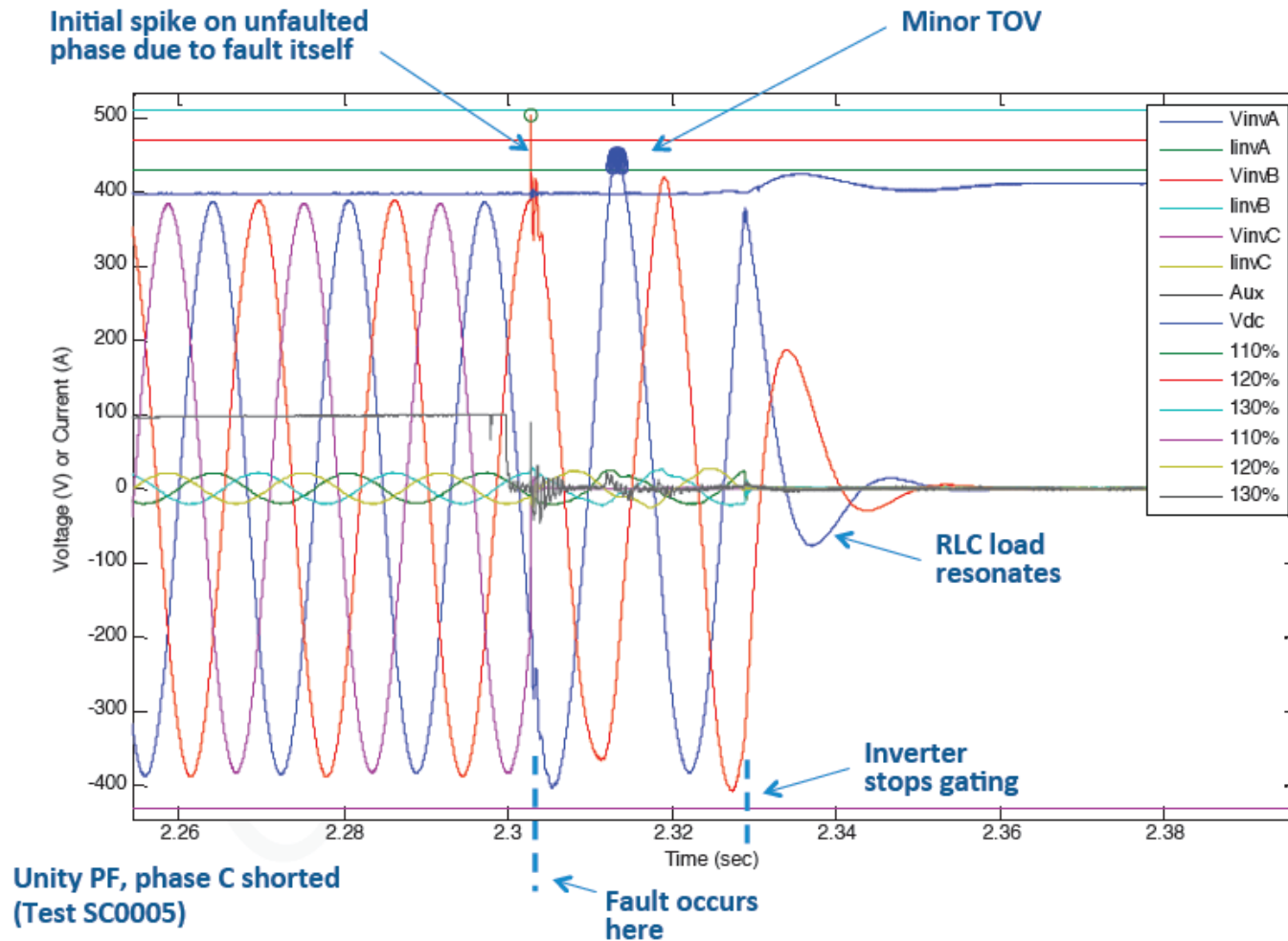
Ground Fault Overvoltage

- Inverters are often best represented as a current source that is power regulated. Therefore, the loads must be considered.
- If the zero-sequence path is not broken, grounding transformers do not mitigate the overvoltage, but can negatively impact circuit protection.

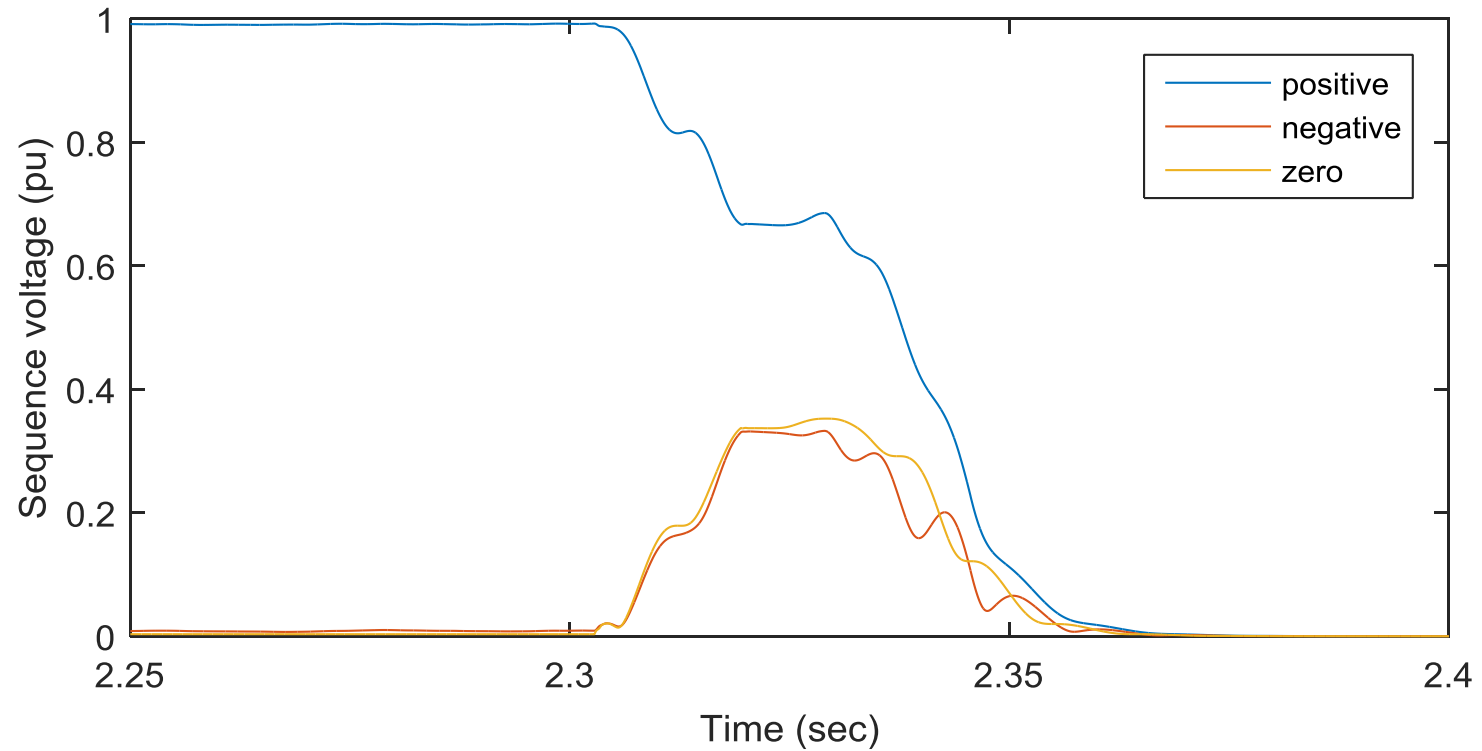
Ground Fault Overvoltage



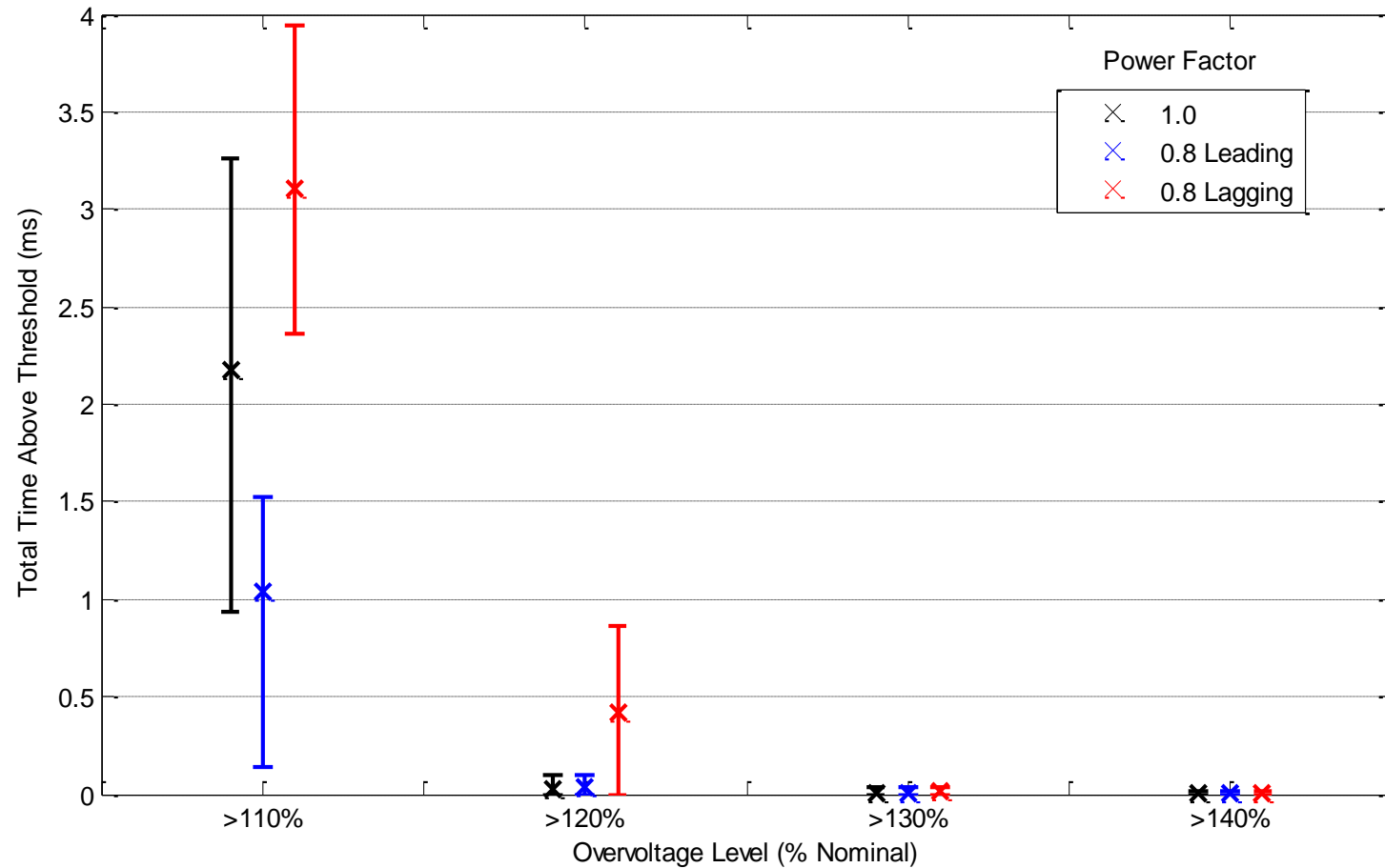
Ground Fault Overvoltage



Ground Fault Overvoltage



Ground Fault Overvoltage

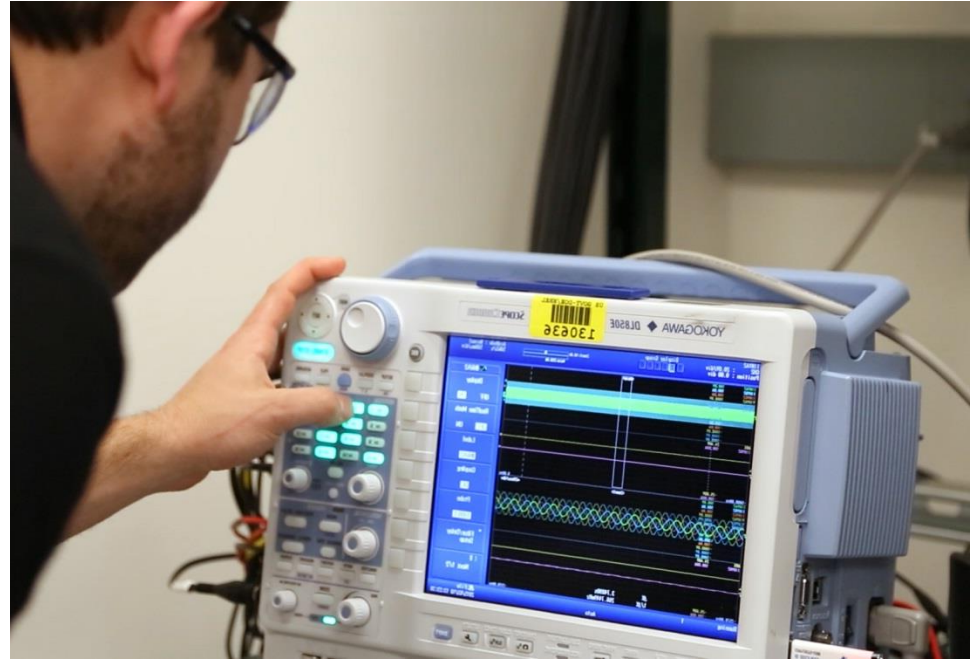


Ground Fault Overvoltage

- Current-controlled inverters will not cause the high, sustained overvoltages at their output terminals associated with neutral shift following a ground-fault.



- Provides justification to improve technical criteria and mitigation approaches involving grounding transformers.



Agenda

Load Rejection Overvoltage Testing

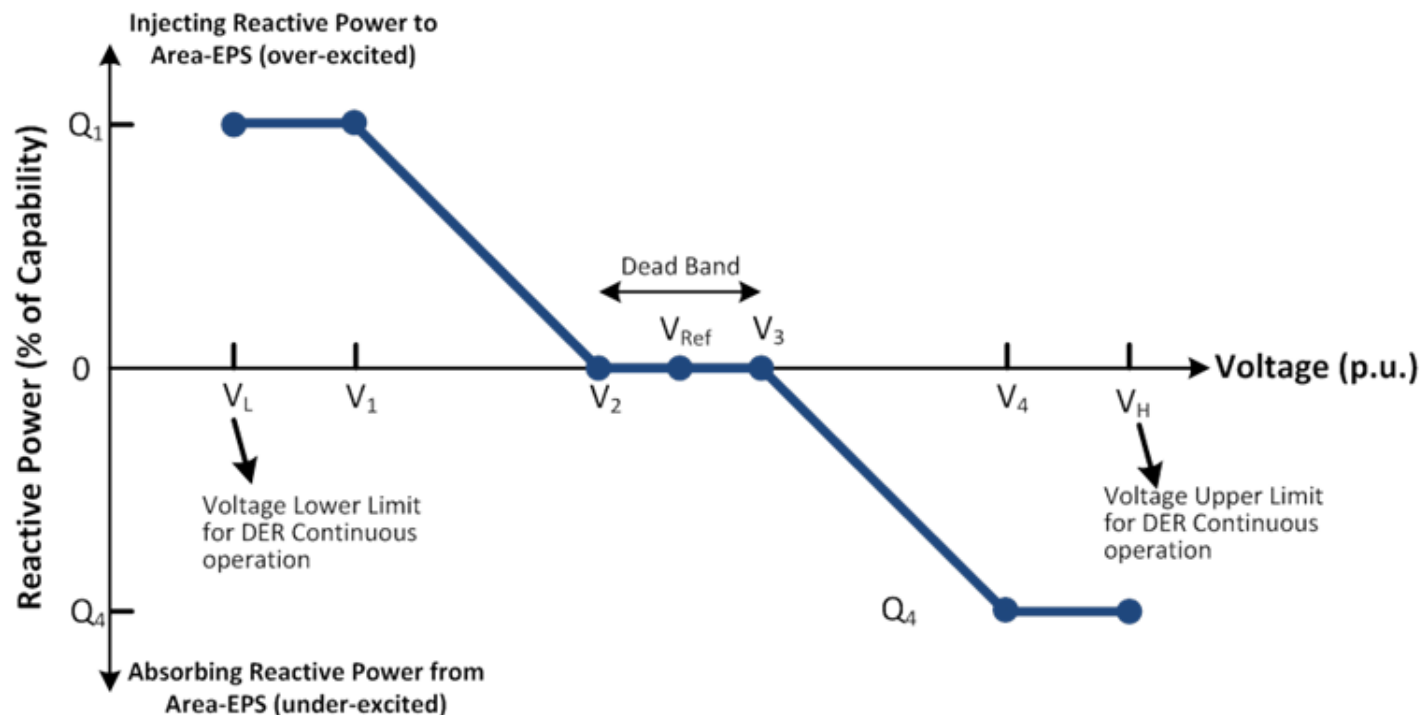
Ground Fault Overvoltage Testing

Ongoing Pilots and Projects



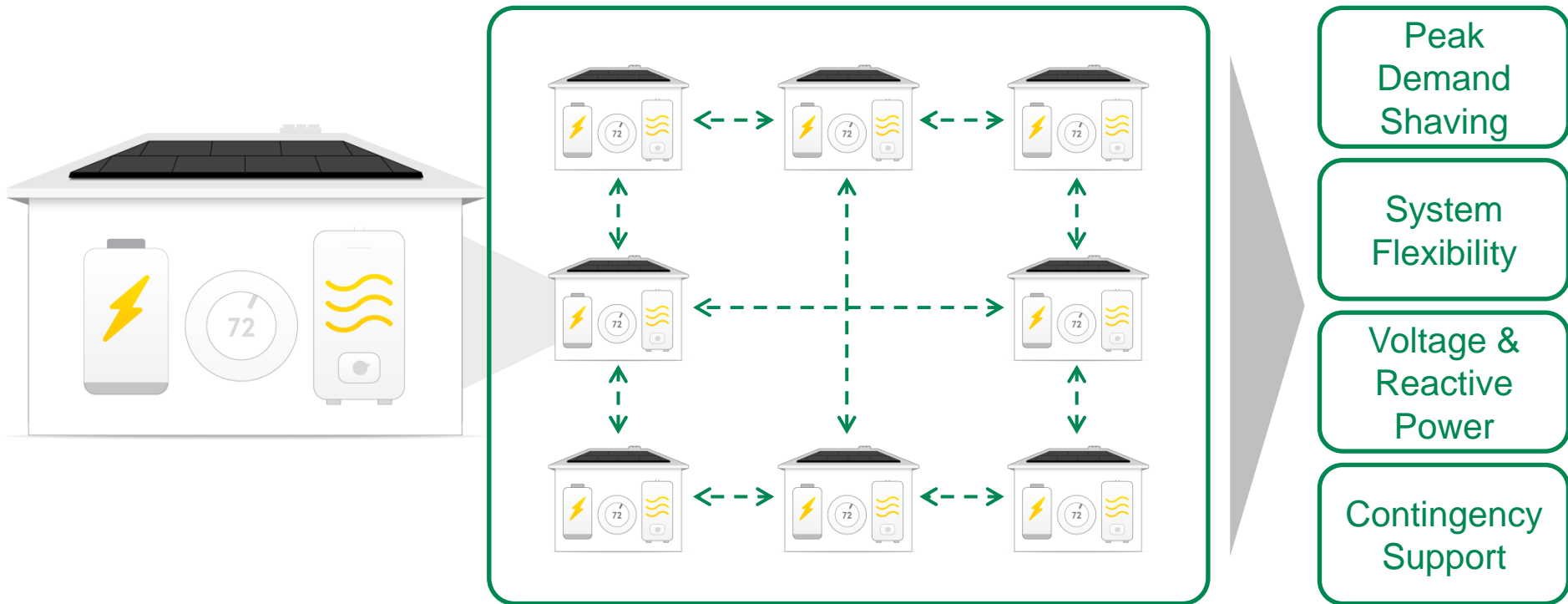
SDG&E Volt/VAR Pilots

- Field test to demonstrate positive impact of advanced inverter Volt/VAR control functionality on circuits with high penetration PV.
- Test baseline, autonomous control, and central control.
- Determine optimal inverter Volt/VAR curves and best use cases for autonomous vs. central control.



SCE DER Aggregation Pilot

Study the degree to which aggregated DERs can offer reliability benefits to the grid.



NREL Multi-Inverter Anti-Islanding



- Prove that active anti-islanding capability does not degrade with multiple inverters.
- Grid-support functions activated including:
 - High/Low Voltage Ride Through
 - High/Low Frequency Ride Through,
 - Autonomous VAR and frequency control
- First time anti-islanding capabilities will be tested at independent points of common coupling.



Questions?

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